Indian J. Phys. **64A** (3), 192-200 (1990)

Nuclear physics with solid state nuclear track detectors in Indian context

B B Baliga
Saha Institute of Nuclear Physics, Calcutta-700 009, India

Abstract : Application of solid state nuclear track detectors (SSNTD) in low energy nuclear physics research is discussed. The first part deals with the experience gained by the Saha Institute group and a number of experiments have been presented. In the second part several feasible experiments which can be undertaken by small groups in the universities have been elucidated.

Keywords : SSNTD, scattering chamber, nuclear scattering, heavy ions, reactions, fission, heavy-ion radioactivity.

PACS Nos : 25.55. Ci, 25.85. Ge, 29.40.-n.

1. Introduction

Nuclear tracks in photographic plates have been known right from the early days of nuclear physics itself in the beginning of this century. These were the early detectors which brought us the information about nuclear interactions and thus helped us to have the early understanding of the nucleus. Whenever, the subject arrived at the cross-roads and new detectors were yet to be conceived of, tracks in emulsion helped to tide over the situation. Thus when high energy nuclear interactions were looked into in the middle of the century, it was again the emulsion which came to our rescue. Similarly, the elucidation of high energy interaction of cosmic ray particles depended on the use of emulsion. Thus they came handy im baloon flights and later in space flights too. The miniaturisation of electronic equipment and the advancement in radio transmission of the signals from space have diminished their use to a certain extent, they still play a role. Thus when new solid state track detectors were discovered where detection was based on the damage caused in the material, it relieved the scientist from the cumbersomeness of the darkroom and the risks of accidental exposure to light of the exposed emulsion plates. Hence intensive activities started to improve the quality of the latter detectors which resulted in the very sensitive CR-39 (DOP) developed at the Berkely Laboratory, and this process is still continuing.

Today, experimental nuclear physicists have a wide choice of these passive detectors, which can be judiciously used to extract the requisite information. The detectors are sensitive to different ionisation and they can be utilised to sort out light ions from heavy ones and so on. Thus CR-39 (DOP) which are sensitive to practically all the charged particles will pose a problem of light ion background when the interest is in heavier fragments. One can get the latter information by using lexan or macrofol without the botheration of light ions. Similarly unwanted heavy ion background can be eliminated in experiments where light ions are of interest using suitable absorbers. However, it should be remembered that these detectors are not of much use where timing information of the interaction or information on sequential processes is sought. This is besides the point that it takes time to etch and scan the detectors mostly manually before any information is gathered. Keeping these limitations in mind we will proceed to consider their role in nuclear physics.

Before dealing with the variety of experiments that can be performed to obtain useful information about the nucleus using these detectors, let me narrate briefly our experience with these detectors both at the accelerators and otherwise. Our group was initiated into this line by the request of Prof S Biswas, in early eighties, for marking his large plastic detectors with the alpha beam of the Variable Energy Cyclotron. During the trials we were impressed with the ability of the detectors to detect alphas so clearly and the energy resolution was also not too bad. Thus we proposed to perform a scattering experiment using these detectors and Prof Biswas enthusiastically encouraged us by supplying the necessary stock of the material and members of his group demonstrated the skills required to use the same. The first scattering experiment was done sometimes in 1983-84 and then followed a series of them using these detectors. It took quite some time to familiarise with handling and interpreting the data. Though a number of preliminary reports were presented in early National Seminars on SSNTD as well as the Nuclear Physics Symposia, a full paper on scattering was sent for publication only last year (De *et al* 1989). One may wonder that it is too long a time. The reason for the delay is due to the fact that these detectors store much more information than we seek. Thus while scanning and plotting the histograms we found that there were tracks of diameters considerably greater than it was possible for alphas to create. We digressed and determined the maximum diameters of the alpha tracks so as to declare that we were observing the heavy ion tracks. It was not possible to generate these heavy ion tracks (at that time) as no laboratory in India was producing any heavy ions beyond alphas on a regular basis. We did the kinematic analysis of the possible reactions in carbon nucleus on which we had the alpha scattering data and found that two reactions were feasible within the energy range of the alphas used. $^{12}C\,(^{4}He,\,^{6}Li)\,^{10}B$, $^{12}C\,(^{4}He,\,^{5}Li)\,^{11}B$. Further the information that we got was that one reaction could not be seen beyond 35° and the other beyond 40° in the laboratory frame. Thus it became imperative on us to scan the angular distribution data carefully at these angles. To our delight we found our conjectures to be correct and all our efforts became concentrated on this aspect of the nuclear reaction and a paper got communicated to Nuovo Cimento (Ganguly *et al* 1987a).

2. Facilities created for conducting experiments

Let me now present the facilities available for undertaking studies of different nuclear physics problems with the variable energy cyclotron. Saha Institute has got a scattering chamber installed in the zero degree port at the beginning of the decade itself and is being extensively used. Figure 1 shows the scattering

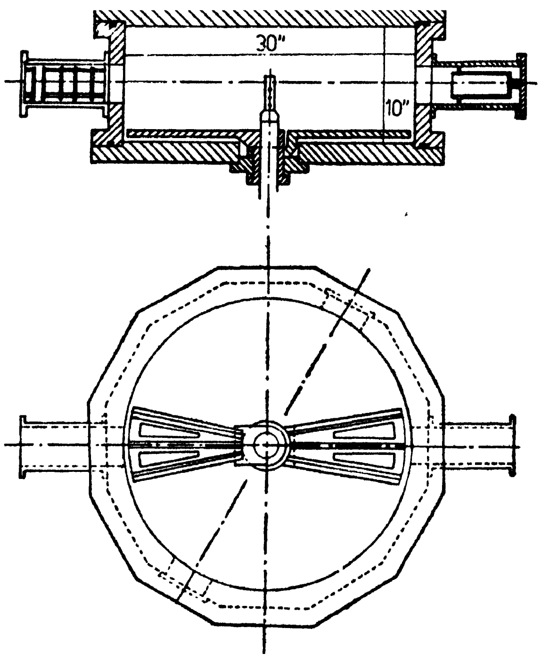

Figure 1. Two views of the Saha Institute scattering chamber installed at Variable Energy Cyclotron.

chamber with two views. However, to do experiments using SSNTDs in the first attempts the detector arms were dismantled and a ring of aluminium was fixed inside the chamber on which were mounted the SSNT detector holders. Figure 2a gives an idea of the layout and Figure 2b depicts the detector holder arrangement. However in some later exposures removal of detector arms from the main chamber was avoided and suitable detector holders for the SSNTDs were mounted on the arms and experiments for limited angles were conducted.

One thing should be kept in mind while conducting experiments with accelerator beams, that the beam currents required are of very low order, say,

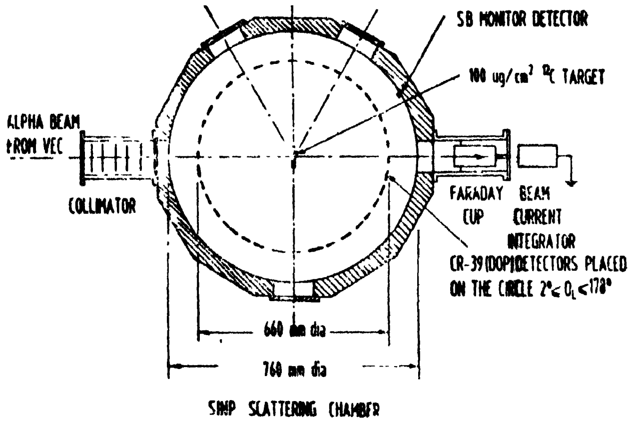

Figure 2(a). Scattering chamber with detector arms removed and an aluminium ring installed.

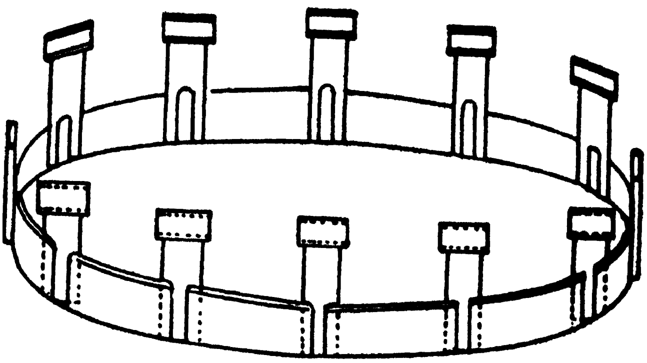

Figure 2(b). Arrangement of detector holders on the aluminium ring.

a few nano-amperes and especially for forward angle recording. Since the detectors are continuously recording, the time for exposure required for forward angles is of the order of a few minutes, otherwise the number of tracks recorded in the detector become so large that it is difficult to extract any meaningful information about the interaction. However, the cross sections fall by orders of magnitude at larger angles in which case higher currents and larger periods of exposures can be used. We have exposed foils in the forward direction upto 25° (for current on target of the order 10 nA) for about 5 – 10 minutes depending upon the cross sections. The same has been increased for backward angles to 30 minutes to one hour. Sometimes higher currents in tens of nA were also used. Thus the time consuming factor in these experiments is the opening and closing of the chamber with new detector foils (and consequent attainment of vacuum) and not the beam exposure time. Since the records are revealed only after etching, may be a few days after the experiment, extreme caution has to be used in determining the exposure time, otherwise the whole experiment can be wiped out.

Recently, a compact small attachment for scattering, reaction and fission studies have been designed, fabricated and put to use with SSNTDs. This gives precise information about angles and considerable experimental convenience. Since these detectors are continuously sensitive one has to be careful in shielding the same until right type of data starts coming. Figure 3 presents a schematic arrangement in this chamber.

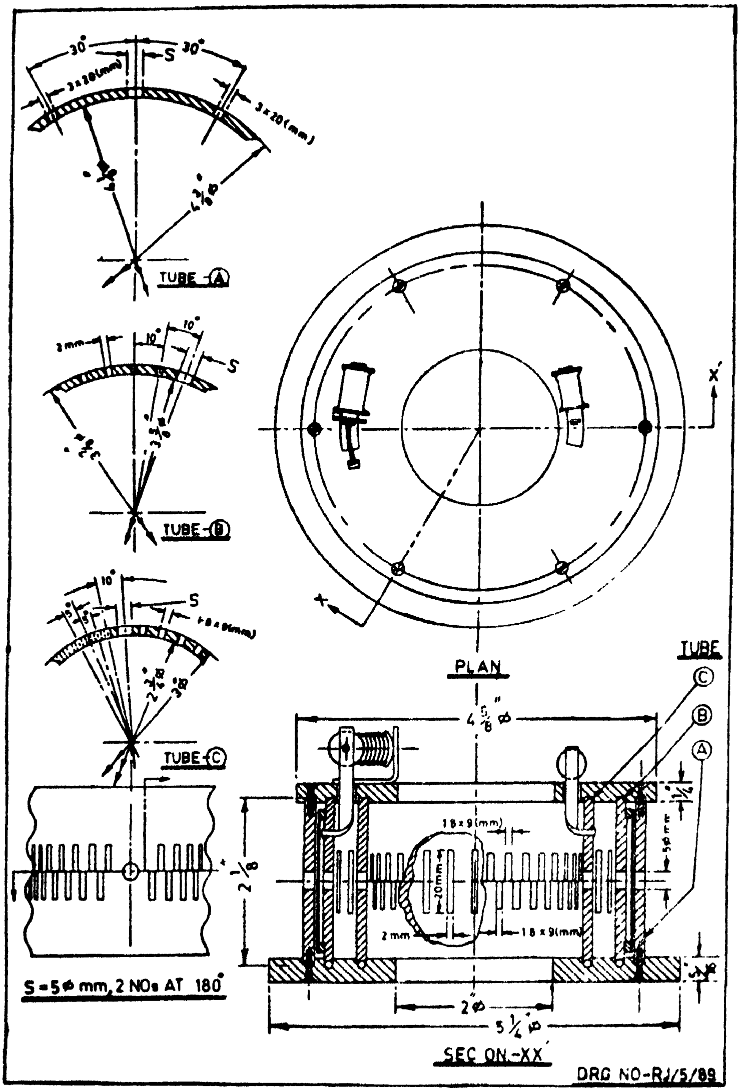

Figure 3. Schematic drawing of small scattering chamber attachment for conducting experiments with SSNTDs. Inner two cylinders marked B and C are mounted on ball bearings and can be moved by remote control. Detector foils are mounted on a ring between cylinders A and B and this is station any. Positions of the slots on cylinders B and C and their movements are depicted in subsidiary sketches.

It may interest some about the fission experiments carried out with the beam. It is a well known fact that many a heavy element undergo fission interaction when sufficient energy is pumped in. It is also known that the angular distribution of the fission fragments is mainly in the forward and backward direction when fission is induced by charged particles whereas in photo fission fragments are emitted at 90° to beam direction. Thus to observe the fore and apt distribution of fission fragments we devised a special chamber attachment which can record all the fission fragments in these two directions. We also included, in one stroke, the energy variation of the incident beam to induce fission and thus obtain excitation function for fission. The target chosen was Au and we could prccure very uniform and pure foil for the experiment. These targets were cut from this stock and detectors (Lexan) were arranged in the forward and backward direction. The whole compact stack was then irradiated with high energy alpha beam and all the detectors recorded the fission fragments. This work was reported at Dehra Dun conference and later a note was published (Ganguly *et al* 1985). We have arrangements for stacks with upto 5 targets. Figure 4a shows the stack with 3 targets and Figure 4b gives the fission fragment distribution with one of the targets.

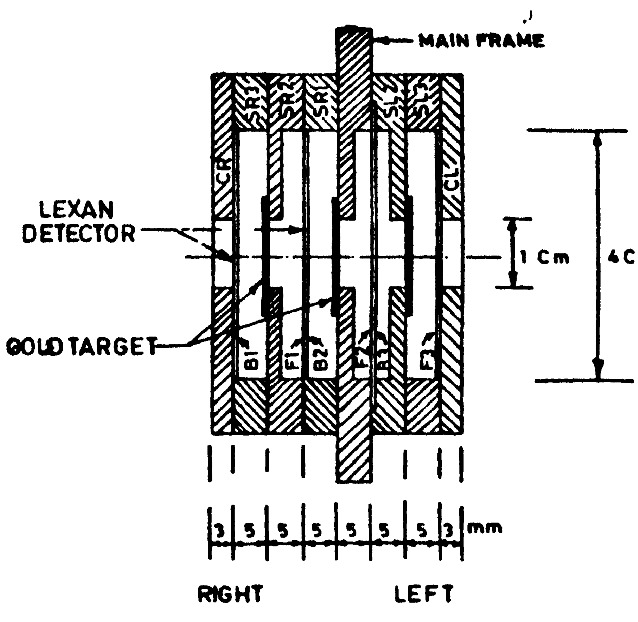

Figure 4(a). Stack of three targets with detectors for fission experiment.

Lest it may give a wrong impression that to do experiment at accelerators using SSNTD, scattering chamber is a must, I like to inform that we did some experiments without using the scattering chamber. Stacks of CR-39 were exposed to neutrons from neutron producing targets bombarded by alpha beam. Neutrons were not only detected in the SSNTDs but also in liquid scintillators, the latter giving a spectrum of neutrons after analysis of the scintillator data. The SSNTD

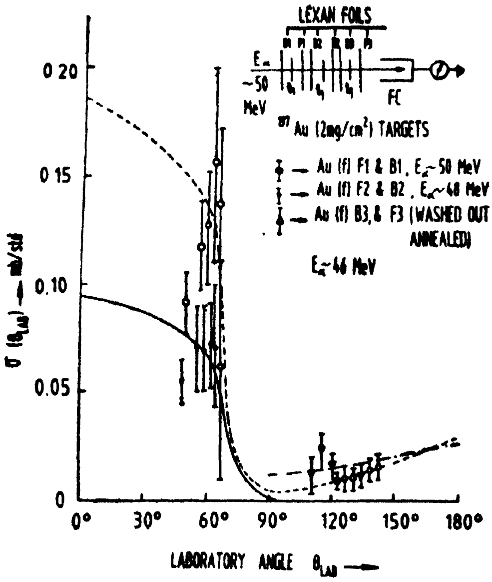

Figure 4(b). Typical fission spectrum obtained.

data was also similarly analysed and the spectrum in the low energy region was reproduced. To obtain the high energy data it turned out that sufficient thickness of the stack had to be exposed which we were not having at that time (Ganguly *et al* 1987 b).

3. Possible research projects

As already outlined all the above experiments can be undertaken by any university group. Our facilities are open for any collaboration or if any group wants to do independent work then too (provided the proper use of the equipment is assured) the facility is made available. We have a few other attachments which can be profitably utilised to obtain data on SSNTDs.

Shape isomerism in nuclear physics is a well known concept which is associated with the second minimum in the fission potential of uranium and transuranium nuclei-short lived shape isomers (half lives > 15 nsec)—which can be studied by recoil distance method using SSNTDs. When bombarded with alpha particles, shape isomers will recoil from the target and after a finite flight distance decay by fission. These delayed fission fragments can be detected by SSNTDs suitably arranged (such that they are not seen by prompt fragments). From the detection of the fission fragments along the detector foil the half lives, angular distribution, cross sections etc. can be measured. Two attachments for the purpose have been designed. Figure 5 gives schematic drawings of two such attachments.

FISSION CHAMBER

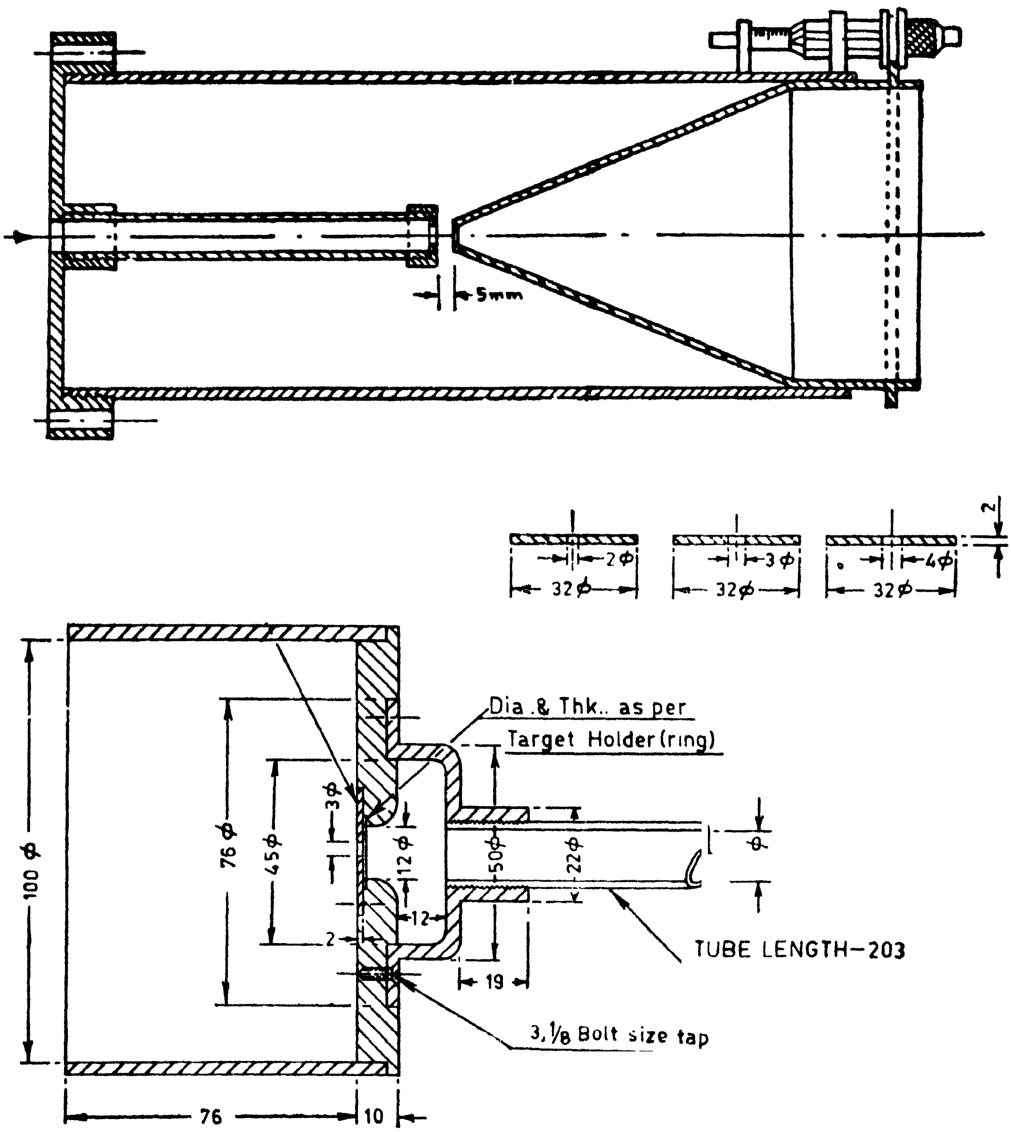

Figure 5. Two schematic drawings of attachments for conducting delayed fission experiment.

Many University laboratories have in-house 14 MeV neutron generators. Mainly these are used for activation analysis. There are a number of (n, α) and (n, p) reactions which can be studied using these neutrons. However, one requires multiple targets from the sama stock of material so that target normalisation is least. Targets with the detectors can be exposed to neutrons in a particular direction from the neutron source and corresponding alphas or protons recorded in the detectors. If the currents are well controlled on the neutron producing target the number of neutrons falling on the target of interest can be estimated and cross sections for the reaction measured.

It is wellknown these days that many radioactive nuclei emit heavy ions and these can be detected. However, the lifetimes are sufficiently long and hence it becomes really difficult to maintain uniform conditions over the conventional detector systems for months together. But the continuously active SSNTD can be utilised for detecting these heavy ions even in the background of alpha particles. We have done some preliminary experiments in our laboratory by exposing CR-39 (DOP) to thin electroplated targets of Uranium and Thorium. Exposures of 15 days to one month reveal definite presence of heavy ions. To identify the heavy ions we are proposing to obtain the signatures of the known heavy ions in CR-39 (DOP) with our low energy heavy ion accelerator. Thus, it is possible for any university department to undertake such experiment and carefully determine the half-lives for heavy ion emission. This information is necessary for understanding the phenomena.

Other nuclear physics experiments that can be undertaken in university laboratory are the type of experiments already initiated by the group at Indian Association for the Cultivation of Science and at NEHU. However, these experiments require exposures to heavy ions beams in foreign laboratories.

Apart from this, in the interdisciplinary area, one can determine environmental radiation, especially radon, using SSNTDs. Many have already undertaken such projects but one should be cautioned that to produce useful data extreme precaution in the experiment has to be employed and the seriousness of purpose exhibited.

Acknowledgments

I am indebted to my colleagues in the laboratory, laboratory assistants and technicians whose work has been reported here. Thanks are due to the Director of VECC for the facilities provided for conducting the experiment and to the Director of Saha Institute of Nuclear Physics for his kind interest in the programme.

References

De T K, Mukherjee R N and Baliga B B 1989 *Nucl. Instrum. Meth.* **B42** 138

Ganguly A K, Chaudhury B and Baliga B B 1985 *Sci. Cult.* **51** 411

— 1987a *Nuovo. Cim.* **97A** 639

—1987b *Int. J. Radiat. Appl. Instrum, Part D* **13** 139